

Curriculum Vitae-abridged

W. TIMOTHY LIU

EDUCATION

University of Washington, Seattle, Washington

PH. D. in Atmospheric Sciences, March 1978

M.S. in Atmospheric Sciences, June 1974

Ohio University, Athens, Ohio

B.S., Summa Cum Laude, in Physics, June 1971

EMPLOYMENT

1979-present Jet Propulsion Laboratory

Principal investigator since 1979. Study ocean-atmosphere interaction and satellite oceanography.

Team Leader of Air-sea Interaction and Climate Team 1989-2005. Supervise a team of meteorologists and oceanographers, and lead their science investigations.

Project Scientist of a series of NASA Scatterometer Missions-NSCAT, QuikSCAT and SeaWinds, 1992-2006. Coordinate and monitor science and validation studies of the science team. Monitor sensor and data system development to meet science requirements.

Ocean Vector Wind Science Team Leader. 1996 Lead the investigators of the NASA selected team

Senior Research Scientist/Principal Scientist since 1993. The position is equivalent to a full professor at major universities.

1971-1979 University of Washington.

Research Associate, 1978-1979. Modeling planetary boundary layer and study turbulence flux measurements from aircraft.

Research Assistant, 1971-1978. Studying the transfer processes across the air-sea interface and in the atmospheric boundary layer leading to M.S. and Ph.D. degrees.

Teaching Assistant Assisting teaching of an introductory course in meteorology and a field experiment course in air-sea transfer processes.

PROFESSIONAL SERVICES

United Kingdom Natural Environment Research Council-Earth Observation Centres of Excellence Steering Committee 2003-present

NASA Global Water and Energy Research Initiative Working Group 2001

Tropical Rain Measuring Mission Science Working Team, 1998-present.

Salinity Sea Ice Science Working Group, 1998-present.

JASON Science Working Team 1997-present.

EOS Distributed Active Archive Center Users Working Group 1994-present.

Interagency Science Working Group on Passive Microwave Vector Wind Sensing, 1995-1997.

- South China Sea Monsoon Experiment Science Working Group** 1994-1996.
- Joint Science Committee Task Force on Air-Sea Fluxes**, 1993-1997. Coordinate and promote international studies of air-sea fluxes.
- Editorial Board, The Atmosphere-Ocean System**, 1993-1998.
- Environmental Task Force**, 1992. Invited member of the Clouds, Radiation, Water Vapor, and Precipitation Panel. To compile for the intelligence community the data need of the environmental scientists.
- NASA TOGA-COARE Science Advisory Committee**, 1991-1994. Advise NASA on participation in the experiment.
- NASA ESTAR** (Electronically Scanned Thinned Array Radiometer) **Science Working Group**, 1990-1995.
- Tropical Rain Measuring Mission Science Team 1991-1993**
- NASA Earth Science & Application Advisory Committee** 1990-1993. Advise the NASA Division on program and policy.
- WCRP Surface Radiation Budget Science Working Group**, 1989-1996.-Plan and implement the production of surface radiative exchange.
- Earth Observing System Investigator Working Group**, 1989-present. Formulate science requirements and lead science research for the project. Member of Payload, Oceanography, Hydrology and Climate Panels.
- NASA TOPEX NSCAT Archiving Working Group**, 1989. Advise NASA on archiving and distributing data for NSCAT and TOPEX Projects.
- International WOCE Working Group on In Situ Measurement for Surface Fluxes**, 1989-1990. Recommend the best method for measuring air-sea fluxes.
- TOGA COARE Science Working Group**, 1989-1992. Refine the objectives, to design the experimental approach, and to define an implementation methodology for the TOGA/COARE. Chairman of Air-Sea Fluxes Subgroup.
- NASA Wetnet**, 1988-1995. Design and implement an interactive science network centered on SSMI data.
- Interagency Sea Surface Temperature Archiving Science Working Group**, 1988-89. Assess the quality and availability of sea surface temperature data.
- WOCE Advisory Group for Model-based Air-sea Flux Estimates**, 1988-1995. Advise WOCE on air-sea fluxes estimates using numerical models.
- TOPEX/POSEIDON Science Working Team** 1987-1997. Formulate science requirements and to conduct research for the joint U.S/French ocean altimetric mission. Member of the Science Steering Group.
- JSC/CCCO Working Group on Air-Sea Fluxes**, 1987-93. Promote the optimal use of oceanographic satellite data for the determination of air-sea interface quantities. Appointed by the Joint Science Committee and the Committee on Climate Changes and the Ocean (CCCO).
- NSCAT Science Working Team** 1986-present. Conduct science research and to formulate requirements for the NASA Scatterometer Project (NSCAT). Chairman of the Subcommittee on Data Level and Contents.
- WOCE/TOGA Working Group on Data Management** 1985-1988. Develop a data management system for WOCE and TOGA.
- WOCE Working Group on Atmosphere-ocean Exchanges**, 1984-1988. Assess present capabilities of describing atmosphere-ocean exchanges of physical properties.

NASA Ocean Energy Fluxes Science Working Group 1984. Assess geophysical retrieval algorithms of DMSP/SSMI (Special Sensor Microwave Imager) and Geosat/altimeter and to review the scientific problems that can be addressed using their geophysical parameters.

Guest Lecturer: (1) NATO Advanced Study Institute at Corsica France, 1983. (2) California Space Institute Summer School on Climate Remote Sensing 1987, (3) University of Southern California-graduate course in tropical oceanography, 1990 and 1992. (4) NASA Summer School on Earth Sciences, 1992.

HONORS AND AWARDS

Distinguished Science Award, Pan Oceanic Remote Sensing Conference Association, 2002

NASA Group Achievement Award 2001-Satellite Ocean Atlas.

Fellow of American Meteorological Society, 2000-

NASA Group Achievement Award, 2000 – Quikscat Mission Team

NASA Group Achievement Award, 1998 - NSCAT Science Team

NASA Exceptional Achievement Medal, 1998 - Leadership in NSCAT Sciences Research

NASA Group Achievement Award 1997 - NSCAT Management and Outreach Visiting Professorship at Ocean University Tsingtao, 1996

NASA Group Achievement Award 1994 - Topex Verification

NASA Group Achievement Award 1993 - Topex Mission Design

NASA Certificates of Recognition 1993 - Hydrologic Balance and Greenhouse Warming

NASA Certificates of Recognition 1991 - Remote Sensing of Turbulent Flux

NASA Medal for Exceptional Scientific Achievement, 1990-Air-sea Interaction Processes

NATO Fellowship to Advanced Study Institute on Air-Sea Interaction, 1978.

Sigma Xi 1975

Phi Beta Kappa 1971

Ohio University Trustee Scholarship 1967-1971

Dean's List 1969-1970

Sigma Pi Sigma 1970

SUMMARY OF PROFESSIONAL ACCOMPLISHMENTS

W. Timothy Liu's experience and expertise are in ocean-atmosphere interaction and application of spacebased observations.

While a student at the University of Washington, Timothy Liu conducted both laboratory and field experiments to study interfacial transport and turbulent transfer in the surface (constant flux) layer over the ocean. His postulation (with Professors Kristina Katsaros and Joost Businger) of the behavior of the moisture transfer coefficients, at low and high winds were unconventional at that time, and led later to the validation effort in the Humidity Exchange Over Sea (HEXOS) experiment and Tropical Ocean Global Atmosphere (TOGA)-Couple Ocean and Response Experiment (COARE) in the eighties and nineties. Its impact is still felt more than two decades later. His formulation of temperature profile and transport theory in the molecular sub-layer, which is based on gas transfer studies, are being used by the communities studying gas transfer and ocean skin layer today.

Timothy Liu developed (with Professor Pearn P. Niiler) the first credible method of using satellite data to estimate evaporation and latent heat flux in the early 1980s, and was one of the first scientists to use a combination of satellite sensors to study the global relation between surface thermal forcing and ocean temperature response. In the past two decade, a generation of scientists have been involved in the estimation of heat flux from space, based on his methodology. With a new generation of microwave radiometers and atmospheric sounders, he has just begun to lead a renewed effort again to retrieve evaporation directly from the radiance measured by spacebased microwave radiometer.

Since he joint JPL, he has been selected to the science teams of numerous space missions, including NSCAT, QuikSCAT, Topex/Poseidon, JASON, TRMM, EOS, Aqua, ERS-1, AMSR, and Aquarius. He has made many innovative science applications of various combinations of these spacebased measurements. His present interest includes relating the fluxes to storage and transport through the depths of the ocean and atmosphere. He is leading research effort to combine a variety of satellite data synergistically to study global climate and environmental changes. He is studying the water balance over global ocean and their influence on terrestrial and cryospheric water cycles.

Through 17 years as Team Leader and 14 years as Project Scientist, Timothy Liu was able to lead various groups of scientists through many cycles of fiscal gyration and changes of national and institutional priority, securing their funding support, communicating and promoting their results, and keeping the team spirit and cohesiveness.

PUBLICATIONS

At the end of March 2006, W. Timothy Liu has 246 publications (not including abstracts), of which 130 are refereed journal articles or reviewed book chapters

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- *246 Xie, S.-P., H. Xu, N.H. Saji, Y. Wang, and W.T. Liu, 2005: Role of narrow mountains in large-scale organization of Asian monsoon convection. *J. Climate*. In press.
- *245 Zheng, Q., R.J. Lai, N.E. Huang, J. Pan, Y. Yuan, and W.T. Liu, 2006: Observation of ocean current response to 1998 Hurricane Georges in the Gulf of Mexico. *Acta Oceanologica Sinica*, 25 (1), 1-14.
- 244 Liu, W.T. and X. Xie, 2006: Moving water to South America as observed from Space, *Proc. of 8th International Conf. on Southern Hemisphere Meteorology and Oceanography*. American Meteorological Society, Boston..
- *243 Han, W., W. T. Liu, and J. Lin, 2006: Impact of atmospheric submonthly oscillations on sea surface temperature of the tropical Indian Ocean. *Geophys. Res. Lett.*, 33, L03609, doi:10.1029/2005GL025082.
- *242 Liu, W. T., X. Xie, W. Tang, and V. Zlotnicki, 2006: Spacebased observations of oceanic influence on the annual variation of South American water balance, *Geophys. Res. Lett.*, 33, L08710, doi:10.1029/2006GL025683.
- *241 Liu, W.T., and X. Xie 2005: Measuring ocean surface wind from space. *Remote Sensing of the Marine Environment*, Manual of Remote Sensing, Third Edition, Vol. 6, , J. Gower (ed,), Amer. Soc. for Photogrammetry and Remote Sens. Chapter 5, 149-178.
- *240 Yan, X.-H., Y.-H. Jo, W.T. Liu, and M.-X. He, 2006: A new study of the Mediterranean outflow, air-sea interactions and Meddies using multi-sensor data. *J. Phys. Oceanogr.*, 36(4), 691-710..

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- 239 Liu, W.T., X. Xie, and W. Tang, 2005: Monsoon, orography, and human influence on Asian rainfall. *Proc. First International Symposium on Cloud-prone and Rainy Areas Remote Sensing*. Hong Kong Chinese Univ. Press.
- *238 Sprintall, J. and W.T. Liu, 2005: Ekman mass and heat transport in the Indonesian Seas. *Oceanography*, 18(4), 88-97,
- *237 Evans, D., W. Alpers, A. Cazenave, C. Elachi,T. Farr, D. Glackin, B. Holt, L.Jones, W.T. Liu, W. McCandless, Y. Menard, R. Moore, and E. Njoku, 2005: Seasat – a 25-year legacy of success. *Remote Sens. Envir*, 94, 384-404.
- 236 Liu, W.T. and X. Xie, 2005: Potential scientific applications of SeaWinds and its follow-on. *Proc. of IGARSS 2005*. IEEE.
<http://216.228.1.34/Conf/igarss05/versions/47683/PID84283.pdf>
- 235 Liu, W.T., X. Xie, and W. Tang, 2005: Oceanic influence on global hydrologic cycle observed from space. *Proc.of IGARSS 2005*, IEEE.
<http://216.228.1.34/Conf/igarss05/versions/47683/PID84601.pdf>
- *234 Lee, T. and W.T. Liu, 2005: Effects of high-frequency wind sampling on simulated mixed layer depth and upper ocean temperature. *J. Geophys. Res.*, 110(C5), C05002, 10.1029/2004JC002746.

- 233 Ebuchi, N. and W.T. Liu (eds), 2005: Synergism of SeaWinds and AMSR. 33pp, <http://airsea.jpl.nasa.gov/publication/paper/SeaWinds-AMSR-synergism-s.pdf>
- 232 Xie, X. and W.T. Liu, 2005: Hydrological budget in the Tropical Pacific. 16th Conf.on Climate Variability and Change, Amer. Meteor. Soc., Boston <http://ams.confex.com/ams/pdfpapers/85220.pdf>
- *231 Jo, Y.-H., X.-H. Yan, B. Dzwonkowski, and W.T. Liu, A study of freshwater discharge from the Amazon River into the tropical Atlantic using multi-sensor data. *Geophys. Res. Lett.*, 32, :02605, doi:10.1029/2004GL021840.
- *230 Liu, W.T. and W. Tang, 2005: Estimating moisture transport over ocean using spacebased observations from space. *J. Geophys. Res.* 110, D10101, doi:10.1029/2004JD005300.
2004-9(119)
- 229 Liu, W.T. and W. Tang, 2004: Oceanic Influence on the precipitation in India and China as observed by TRMM and QuikSCAT. Proc. TRMM Conf. <http://airsea.jpl.nasa.gov/publication/paper/Liu-Tang-2004-trmm.pdf>
- *228 Liu, Q., X. Jiang, S.-P. Xie, and W.T. Liu, 2004: A gap in the Indo-Pacific warm pool over the South China Sea in boreal winter: seasonal development and interannual variability. *J. Geophys. Res.*, 109,C07012, doi:10/1029/2003JC002179.
- *227 Hashizume, H. and W. T. Liu, 2003: Systematic error of microwave scatterometer wind related to the basin scale plankton bloom. *Geophys. Res. Lett.*, 31, L06307, doi:10.1029/2003GTL01841.
- *226 Zhou, Y.H., X. H. Yan' X. L. Ding, X. H. Liao' D. W. Zheng' J. Y. Pan' M. Q. Fang, M. X. He, W. T. Liu' 2003: ,Excitation of non-atmospheric polar motion by the migration of the Pacific Warm Pool, *J. Geodesy*, 78.109-113
- *225 Yan, X.-H., J. Pan, M.-X. He, W.T. Liu, and Y.-H. Jo, 2003: The role of winds on estimation of the ocean heat storage anomaly using satellite data. *J. Geophys. Res.*, 109. doi:10.1029/2003JC002202.
- *224 Tang, W., W.T. Liu, and B.W. Stiles, 2003: Evaluation of high-resolution ocean surface vector winds measured by QuikSCAT scatterometer in coastal region. *IEEE Trans. Geoscience and Remote Sens.* 42, 1762-1769.
- *223 Pan, J. X-H Yan, Y.H. Jo, Q. Zheng, and W.T. Liu, 2003: A new method of estimation of the sensible heat flux under unstable conditions using satellite vector winds, *J. Phys. Oceanogr.*, 34,968-977.
- *222 Yan, X.-H., Y.-H. Jo, W.T. Liu, and M.-X. He, 2003: Multi-sensor study of the Mediterranean outflow and Meddies at 1000-meter depth. *J. Phys. Oceanogr.*, in press.
- *221 Jo, Y.-H., X.-H. Yan, J. Pan and W.T. Liu, 2004: Sensible and Latent Heat Flux in the Tropical Pacific from Satellite Multi-Sensor Data. *Remote Sens. Environment*, **90**, 166-177.
- *220 Zheng, Q., P. Clemete-Colon, X.-H. Yan, W.T. Liu,, N.E. Huang, 2004: Satellite synthetic aperture radar detection of Delaware Bay plumes: jet-like feature analysis. *J. Geophys. Res.*, **109(C3)** 10, 1029/2003JC002100.
- 219 Liu, W.T, W. Tang, X. Xie, 2004: Long-term variability of ocean surface winds. Proc. Decadal Climate Variability Workshop, Kona. <http://airsea.jpl.nasa.gov/publication/paper/Liu-etal-2004-decadal.pdf>
- 218 Liu, W.T., S.-B. Kim, T. Lee, Y.T. Song, W. Tang, and R. Atlas, 2004: Scientific Impacts of Wind Direction Errors. JPL Publ. 04-008, Jet Propulsion Laboratory,

- Pasadena, 19 pp. <http://airsea.jpl.nasa.gov/publication/paper/Liu-et-al-2004-winderror.pdf>
- 217 Lin, I-I, C.C. Wu, K.A. Emanuel, W.T. Liu, and I-H. Lee, 2004: The rapid intensification of super-typhoon Maemi (2003) when encountering a warm ocean eddy. *26th Conf. on Hurricanes and Tropical Meteorology*, Miami, Amer. Meteor. Soc., Boston.
- 216 Liu, W.T. and W. Tang, 2004: Calibration/validation of SeaWinds on ADEOS-2, in Sensors, Systems, and Next-Generation Satellites VII, edited by R. Meynart, S.P. Neeck, H. Shimoda, J.B. Lurie,, M.L. Aten, Proc. Of SPIE, Vol. 5234, SPIE, Bellingha, WA, 47-52.
- 2003 13[110]
- 215 Liu, W.T., 2003: Scientific Opportunity Provided by SeaWinds in Tandem. *JPL Publications* 03-12, Jet Propulsion Laboratory, Pasadena, 38 pp.
<http://airsea.jpl.nasa.gov/publication/paper/Liu-et-al-2003-tandem.pdf>
- *214 Yueh, S.H.* , B. Stiles, and W. T. Liu, 2003: QuikSCAT Geophysical Model Function and Winds for Tropical Cyclones. *IEEE Trans. Geophys. Remote Sens.*, 41, 2616-2628.
- *213 Chen, D., W. T. Liu, W. Tang, and Z. Wang, 2003: Air-sea interaction at an oceanic front: implications for frontogenesis and primary production. *Geophys. Res. Lett.*, 30(14), 1745, doi:10.1029/2003GL017536.
- *212 Yu, J. Y., and W.T. Liu, 2003: A liner relationship between ENSO intensity and tropical instability wave activity in the eastern Pacific ocean. *Geophys. Res. Lett.*, 30(14), 1735, doi: 10.1029/2003GL017176.
- *211 Xie, S.-P., Q. Xie, D. Wang, and W.T. Llu, 2003: Summer upwelling in the South China Sea and its role in regional climate variations. *J. Geophys. Res.*, 108(C8), 3261, doi:10/1029, 2003JC001867.
- *210 Lin, I-I, W. Alpers, and W.T. Liu, 2003: First evidence for the detection of natural surface films by the scatterometer. *Geophys. Res. Lett.*, 30(13),1713, doi:10.1029/2003GL017415.
- *209 Hu, H., and W.T. Liu, 2003: Oceanic thermal and biological responses in Santa Ana Winds, *Geophys. Res. Lett.*, 30(11), 1596, doi:10.1029/2003GL017208.
- *208 Lin, I-I, W.T. Liu, C.-C. Wu, G. T.F. Wong, C.Hu, Z. Chen, W.-D. Liang, Y. Yang, and K.-K. Liu, 2003: New evidence for enhanced ocean primary production triggered by tropical cyclone. *Geophys. Res. Lett.*, 30(13), 1718, doi:10.1029/2003GL017141.
- *207 Bourras, D., and W. T. Liu, 2003: Regional correction of ocean surface specific humidity derived from satellite sensor data. *Remote Sens. Lett. , Internat. J. of Remote Sensing*, 24(15), 3163-3169.
- *206 Yu, L., R.A. Weller, and W.T. Liu, 2003: Case analysis of a role of ENSO in regulating westerly wind bursts in the Western Equatorial Pacific. *J. Geophys. Res.*, 108(c4), 3128, doi:10.1029/2002JC001498.
- *205 Bourras, D, W.T. Liu, L. Eymard, and W. Tang, 2003; Evaluation of latent heat fluxes fields from satellites and model during the SEMAPHORE experiment, *J. Applied Meteor.*, 42(2), 227-239.

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- *204 Lin, I.-I.; W.T. Liu, C.-C. Wu, J.C. Chiang, and C.-H. Sui, 2003: Satellite observations of modulation of surface winds by typhoon-induced upper ocean cooling. *Geophys. Res. Lett.*, Vol. 30(3), 1131, doi:10.1029/2002GL015674.
- *203 Polito, P., and W.T. Liu, 2002: Global characterization of planetary waves at several spectral bands. *J. Geophys. Res.*, 108 (C1), 3018, doi:10.1029/2000JC000607..
- *202 Bourras, D., W. T., Liu, L. Eymard, and W. Tang, 2003: Evaluation of Latent Heat Flux Fields from Satellites and Models Over the SEMAPHORE Region. *J. Appl. Meteor.*, 42, 227-239, 2003.
- 201 Lin, I-I, and W.T. Liu, 2003: Oceanic biological response to a typhoon. *Proc. 12th Conf Satellite Meteor. And Oceanogr. Amer. Meteor. Soc.*, Boston,,
- 200 Hu, H., and W.T. Liu, 2003: Satellie observations of air-sea interaction during a Santa Ana event, *Proc. 12 Conf. Interaction of Sea and Atmos.*, Amer. Meteor. Soc., Boston,
2002-19 [97]
- *199 Liu, W.T., 2002: Satellite Remote Sensing: Wind, Surface. *Encyclopedia of Atmospheric Sciences*, 1979-1984, J.R. Holton, J.A. Pyle, and J.A. Curry (eds), Academic Press. London.
- *198 Pan, J., X.-H. Yan, Q. Zheng, W. T. Liu, and V. Klemas, 2002: Interpretation of satellite ocean surface wind vector EOFs in the Northwest Pacific, *Rem. Sens. Environ.*, **84**, 53-68.
- *197 Jo, Y. -H., X.-H. Yan, J. Pan, M.-X. He, and W.T. Liu, 2002: Calculation of the Bowen Ratio in the tropical Pacific using sea surface temperature data. *J. Geophys. Res.*, **107**(C9), 3134, doi:10.1029/2001JC001150.,
- *196 Xie, S.-P., J. Hafner, Y. Tanimoto, W.T. Liu, H. Tokinaga, and H. Xu, 2002: Bathymetric Effect on the Winter Climate through the Sea Surface Temperature in the Yellow and East China Seas. *Geophys. Res. Lett.*, 29(24),2288, doi:10.1029/2002GL015884..
- *195 Yan, X.-H.,Y. Zhou, J. Pan, D. Zheng, M. Fang, X. Liao, M. He³ , W. T. Liu, X. Ding, 2002: Western Pacific warm pool excitation, Earth rotation and El Niño Southern Oscillations. *Geophys. Res. Lett.* 29(21). 2032, doi:10.1029/2002GL015685.
- *194 Liu, W.T. and X. Xie, 2002: Double Intertropical Convergence Zoens – a new look using scatterometer. *Geophys. Res. Lett.*, 29(22), 2072, doi:10.1029/2002GL015431..
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- *192 Hashizume, H., S.-P.Xie, M. Fujiwara, M. Shiotani, T. Watanabe, Y. Tanimoto, W.T. Liu, K. Takeuchi, 2002: Direct observations of atmospheric boundary layer response to slow SST variations over the eastern equatorial Pacific, *J. Climate*, 15,3379-3393.
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- 186 Gautier, C., C. Jones, C. P. Peterson, and W.T. Liu, 2002: Satellite observations of latent and sensible heat fluxes in the tropical Pacific Ocean. *Proc. PORSEC '02*, Vol. 1-298-303.
- *185 Velden, C., K. Bruske, C. Kummerow, W.T. Liu, J. Simpson, S. Braun, and R. Anthes, 2002: The burgeoning role of weather satellites. *Coping with Hurricanes*. Chapter 11, 217-218, R. Simpson, M. Garstang, and R. Anthes (eds.), Amer. Geophys. Union.
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- *182 Liu, W.T., X. Xie, W. Tang, and S.V. Nghiem, 2002: Wind Changes over the Western Pacific. *East Asia and Western Pacific Meteorology and Climate*. **Vol. 1**, 27-37, World Scientific Co., London.
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- *180 Yeh, H.-C., T.-J. G. Chen, and W. T. Liu, 2002: Kinematic characteristics of a Meiyu Front detected by the QuikSCAT oceanic winds. *Mon. Wea. Rev.*, **130**, 700-711.
- 179 Tang, W. and W.T. Liu, 2002: Moisture advection and fresh water flux over oceans. *16th Conf. on Hydrology*, 24-28, Amer. Meteor. Soc., Boston.
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- *176 Liu, W.T., 2002: Progress in scatterometer application, *J. Oceanogr.*, **58**, 121-136. 2001-12 [78]
- *175 Milliff, R.E., M.H. Freilich, W.T. Liu, R. Atlas, W.G. Large, 2001: Global ocean surface vector wind observations from space. *Observing the Oceans in 21st Century*, **Chapter 2.2**, 102-119, C.J. Koblinsky and N.R. Smith (eds), Bureau of Meteorology, Melbourne.
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- *172 Pan, J., X.-H. Yan, Q. Zheng, and W.T. Liu, 2001: Vector empirical orthogonal modes of the ocean surface wind variability derived from ERS-1/2 scatterometer data. *Geophys. Res. Lett.*, **28**, 3951-3954.
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